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A METHOD OF NUMBERING PLANTS IN PEDIGREE CULTURES[1]

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ABOUT fifteen years ago, Dr. H. J. Webber (1906, p. 308) introduced into the plant-breeding work of the United States Department of Agriculture a simple and convenient method of pedigree numbering. This method has three essential features: (1) the use of an initial "series number" for each hereditary line or group of lines, the sets of series for different crops being numbered separately; (2) the use of letters for particular parental combinations in a hybrid series; (3) the use of numbers separated by dashes to designate individuals of successive generations.

For example, with cotton, Series 1 might represent selection for longer lint, within the variety Columbia; 1–1, 1–2, etc., would then designate the plants first selected (P_1 generation), and 1–1–5 would designate a plant of the second or F_1 generation.

Similarly, Series 2 might represent a cross between two varieties (for example, Columbia ♀ × Truitt ♂), and Series 3 the reciprocal of this cross. Each combination of "individuals" (plants, branches, or single flowers, as desired) within a hybrid series is represented by a letter, as in 2A, 2D. The F_1 plants are then designated by numbers written after the letters, as in 2A1, 2D6, and the numbers for later generations follow dashes exactly as in a non-hybrid series (for example, 2A1–5). The use of letters thus characterizes hybrid series.

This system of numbering, then, uses simple linear pedigrees for all cases, beginning a new pedigree whenever two lines of descent are combined by crossing.[2] It is adapted to self-fertile organisms, and its convenience and usefulness obviously increase with the frequency of selfing. Pearl's (1915) "system of recording types of mating," on the other hand, is especially adapted to diœcious and self-sterile organisms, and in general its usefulness for recording or presenting data increases with the frequency of crossing.

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Several systems similar to Webber's have been described in recent genetical papers; these schemes usually differ mainly in the method of indicating the "series" or "families." In Jennings' (1916, p. 415) system for asexual reproduction with the animal Difflugia, for instance, each "family" is a pure line descended from one selected individual; each pedigree number, consequently, begins with a simple number assigned to the P_1 individual. Here we have the simplest possible form of pedigree numbering. With the higher plants, however, we need some special provision for cases of crossing, and also some method of distinguishing asexually produced individuals from those produced sexually.

Belling (1914, pp. 309–10),[3] for Stizolobium crosses, uses for each series the initials of the common names of the parent species (*e. g.*, VL for velvet bean ♀ × Lyon bean ♂); this is practicable because the crosses involve only a small number of named forms, themselves appearing practically constant. For the same reasons, the P_1 plants, and usually the F_1 also, are not individually indicated in published pedigrees; VL3 is an F_1 plant, and VL3–7 or VL–7 an F_2 plant. The obvious result of this procedure is a gain in both clearness and brevity of presentation.

Hayes and East (1915, p. 3) use for maize crosses a scheme that resembles Belling's in its direct indication of the parentage of hybrids. "The various races were given different numbers as No. 10 flour corn and No. 5 flint corn.'' Then the F_1 hybrids would be designated, for example: (10 × 5)–1, (10 × 5)–2, (5 × 10)–1, etc. If, however, the individual P_1 plants are regularly indicated in the series numbers, these numbers tend to become unwieldy, particularly if the P_1 plants themselves have somewhat lengthy pedigrees. In cases where this objection does not apply, and where Belling's method is inadequate, Hayes and East's scheme has some advantage in the immediate significance of the series numbers of hybrids.

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[2] Except in cases where vicinism is undiscovered or ignored.

[3] Or see Fla. Agr. Exp. Sta. Report for year 1913, 1914 or 1915.

Of the systems described, Webber's seems most generally applicable to work with the higher plants, though the others may be somewhat more convenient in certain cases. I wish to present several additions to that system, designed in part to provide for somatic variation and polyembryony.

First, capital letters may be used, as is often done, for various special purposes. For instance, letters are sometimes added to distinguish particular types; Shull (1908, p. 60), in describing his system of pedigree records, restricts letters (aside from Roman numerals) to this use, and Hayes and East (1915, p. 4) use them to designate floury and flint-like types of maize kernel. When temporary lot numbers are used, ''L'' prefixed to these numbers will distinguish them from any others. Again, Arabic numerals preceded by ''R'' seem more convenient than Roman numerals as used by Shull (1908, p. 60) to designate rows in field cultures—giving, for instance, R1, 3 (row 1, plant 3) for I, 3, and R28, 26 for XXVIII, 26. I would suggest that capital letters, and capitals only, be employed for such miscellaneous purposes.

Second, small letters may be used for the indication of parts of individuals, whether the parts remain attached or are separated in vegetative propagation.[4] Then, ''–51a'' in a Citrus pedigree will indicate a particular part of tree 51 in a certain generation of that series—

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[4] This is to replace a method of indicating parts of individuals by means of fractions.

perhaps a part permanently marked, and noted in the records, because of some somatic mutation. In the same way, a small letter affixed to any individual designation of a plant not in a pedigree culture, such as, for instance, the number of a tree in a field experiment, may be used to indicate a particular branch. A small letter used alone will indicate a "generation" of vegetative propagation; for example, in the case mentioned above, "–51a–a" and "–51a–b" would be trees budded from the mutant branch "–51a."[5]

Third, small letters affixed to the series number may be used to designate individuals of the first (or P_1) generation of any series, *whether hybrid or not.*[6] The definition of *individual* would necessarily be determined and recorded for each type of work; where desired, the "individual" may be a branch, or even a single bud or fruit. Thus, in my work with Citrus, a letter is assigned to each self-pollinated branch giving seedlings. For example, series 28 consists of descendants of selfed Valencia orange; "28a," then, indicates one bagged branch of Valencia, "28b" another branch, etc. The F_1 progeny will be 28a–11, 28a–12, 28b–32, etc.

For a hybrid series, on this plan, two letters are used to designate the two parents, the letters being independent of those used in the corresponding non-hybrid series. For example, my Citrus series 27 represents Valencia orange ♀ × Imperial pomelo ♂, and "27aa" designates a cross between two particular branches. 27aa–21, then, will be an F_1 hybrid.

Similarly, in my work with Matthiola mutants, series 23 indicates the cross Snowflake ("normal") type ♀ × Slender type ♂. "23ea" designates the combination of two particular individual *plants,* not of two particular *branches* as with Citrus.

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[5] The complete pedigree numbers might be 28a–32–51a–a and 28a–32–51a–b (see below).

[6] In cases where the initial parents of a series are selected from larger groups requiring designation of individuals, the plants of these larger groups may be given temporary numbers. For example, my Raphanus series 14 began with plants from one lot of commercial seed of one variety, numbered 14, 1; 14, 2; 14, 3; etc. In the next generation, 14, 3 became 14a, and 14, 16 became 14b.

Thus with Matthiola a series starts with the crossing, in a given direction, of two apparently uniform *seed-reproduced types,* while with Citrus a series starts with the crossing of two *clons.* In another case it might be desirable to ignore some evident genetic variation in features not being studied, and to base the delimitation of the series on genetic differences of seed-reproduced P_1 individuals in some particular feature under consideration (*e. g.,* in color characters).

Fourth, in cases where polyembryony is to be expected nine numbers (1 to 9), instead of one, may be given, so far as needed, to the product of each seed. Thus, with the Citrus cross mentioned above, the first seed will be assigned the numbers 27aa–11 to 27aa–19, the second seed the numbers 27aa–21 to 27aa–29, etc.[7] The actual plants from the first three seeds are therefore designated as follows:

Seed No. 1 (2 plants), 27aa–11 and 27aa–12.
Seed No. 2 (2 plants), 27aa–21 and 27aa–22.
Seed No. 3 (1 plant), 27aa–31.

If, then, two trees are budded from tree 27aa–31, these will be 27aa–31–a and 27aa–31–b.

It may be objected that this treatment of polyembryony gives misleading numbers to plants from adventitious embryos. It may, however, be impossible in many cases to differentiate positively these asexually produced progeny before maturity, if at all without progeny tests, and the probable inapplicability of some of the numbers must be kept in mind. Where, as with crosses of *Citrus trifoliata* with Eucitrus species, the strictly maternal individuals can be separated at an early stage, they can be discarded; or, if such plants are to be kept, and their exact origin indicated, letters may be used, thus:

43aa–11 (true hybrid).
43aa–1a (for 43aa–12) } (plants from adventitious or
43aa–1b (for 43aa–13) } asexually produced embryos).

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[7] The seeds themselves might be called 27aa–10, 27aa–20, etc.

By thus inserting letters in the hybrid number, to designate the second and third plants, we indicate the vegetative origin of these plants, and also their quasi-sib relation to the true hybrid.

Open pollination, or lack of protection of flowers in general, can be indicated in the numbers, if this seems desirable, by underscoring the proper letter or number,—the use of two letters with the series number for hybrids making it possible to do this with the pollen parent as well as with the seed parent.

An incidental advantage over the original plan results from the use of letters with the series number in the way here indicated. This consists in the fact that the numbers for hybrid and non-hybrid series are thus made symmetrical in relation to the number of generations involved. As an illustration we may take the case of the Matthiola cross mentioned above. This cross was made in 1914, and the hybrid seeds were planted, together with seeds from selfed parents of the same types, in 1915 and 1916. Corresponding to the F_1 hybrids 23ea–1, etc., we have the F_1 selfed progeny 19a–1, etc., from a Snowflake parent, and 25c–1, etc., from a Slender parent, while by the original method these three numbers might be 23G1, 19–1–1, and 25–3–1.

As will readily be seen, this scheme is elastic; if the five main features stated above are adopted, different workers may add, modify, or omit various details, and still use numbers intelligible to each other with little or no special explanation. Further, the method of designating series and initial individuals is essentially independent of the other features suggested, so that any of the latter features may be adopted without the former.

All the schemes so far discussed give *cumulative* numbers, which include the whole pedigree from the P_1 individuals down. Shull (1908, pp. 59–64) has described a non-cumulative system, in which individuals have only temporary numbers (in the field depending on row and position in row) until selected as parents. Each parent is given the number of the notebook page on which its progeny are to be described, preceded by two figures indicating the year in which those progeny are grown; *e. g.,* 06230 is a parent whose progeny are grown in 1906 and described on p. 230 of the 1906 notebook. Only parental and grandparental numbers (*e. g.,* 0557.230 for the case just mentioned) are shown at the head of each notebook page, but these numbers permit ready reconstruction of pedigrees from the pages indicated. The labels bear only the parental number.

In Shull's scheme, then, there is no cumulation beyond the second generation, even in the numbers as written in the notebook. The numbers would include 4 to 8 figures (*e. g.,* 083.7, or 05157.230) in the notebook and 3 to 5 figures (*e. g.,* 097, or 06230) on labels. In the scheme here suggested there is a continuous cumulation; a plant of the second or F_1 generation is usually represented by 3 to 7 letters and figures (*e. g.,* 5b–8, or 32ba–251), and after from 2 to 4 more generations the numbers begin to be decidedly unwieldy. The greater inconvenience and danger of error in copying these larger numbers would seem, however, to be largely offset by the growing familiarity to the worker of the earlier part of a pedigree, and by the identity of the temporary and permanent designations of individuals. Further, the page-to-family feature would be inconvenient in some cases, where several or many actual pages are given to one progeny lot and so would require the same number.

With a cumulative system, the simple device of using temporary yearly lot numbers on individual labels will obviate the necessity of writing a long pedigree number for each plant. If the full number is written in the notebook and on each lot label, together with the lot number (*e. g.,* L1 = 16aa–6–3–44–18–3), and the latter alone on the individual labels if these are used, much work can be saved. In an extreme case, the parents belonging to a given series which are included in a given culture can be arbitrarily made the initial (P_1) individuals of a new series.

The system here presented has been used for two or three seasons' work with the two types of hybridization mentioned above, with Raphanus hybridization beginning with highly heterozygous material, and with pure-line breeding of the tepary bean (Phaseolus). It appears, so far, to be adequate and generally satisfactory for all these types of work.

SUMMARY

This paper describes a system of pedigree numbering adapted to various types of genetical work with the higher plants.

Other similar systems secure greater brevity or clearness in certain cases, but are usually of less general applicability; the main differences relate to the designation of series and their initial individuals.

This system provides for polyembryony and somatic variation, and permits of the addition of various other refinements in cases where they may be needed. The basic scheme is perhaps as simple and convenient as is consistent with use for all purposes without change in essential features.

In this and similar systems, the numbers are cumulative; Shull's non-cumulative system has both advantages and disadvantages in comparison.

To summarize the most essential features of the proposed method: (1) the series for a given plant (genus or species) are numbered consecutively; (2) the initial "individuals," as defined in the records, are denoted by small letters affixed to the series numbers; (3) in each following generation the individuals are numbered (if sexually produced) or lettered (if asexually produced), an affixed letter indicating a particular part of an individual; (4) reproduction or propagation is always indicated by a

dash;[8] (5) capital letters are employed for miscellaneous special uses.

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[8] Of course, a period may be used, as is done by Jennings (1916) with Difflugia, with a saving of space but possibly a greater liability to error in copying.